I – Problem Statement Title (EQ 002)

Response Spectrum Method for Near-Field Ground Motions

II – Research Problem Statement

Question: Are existing response spectrum methods applicable to near-field ground motions?

Caltrans SDC recommends the CQC modal combination rule for dynamic analysis. This and other response spectrum combination rules are based on certain assumptions regarding the ground motion stationarity, duration and bandwidth, which may be violated by near-field ground motions. This research aims at examining this problem and developing an accurate response spectrum method for application to near-field ground motions, including consideration of spatial variability.

III – Objective

STAP Roadmap Outcome: 7 - Improved Understanding of Seismic Hazards.

1. Develop a better understanding of the characteristics of near-field ground motions and develop appropriate probabilistic models.
2. Quantify the error involved in the application of CQC and other modal combination rules for assessment of seismic demand to near-field ground motions.
3. Develop a new response spectrum method by stochastic modeling and random vibration analysis of near-field ground motions. The combination rule shall retain the essential simplicity of the CQC rule for practical use.
4. Extend the method for application to near-fault bridges subjected to differential support motions.

IV – Background

The response spectrum method has proven to be an effective and accurate method for seismic dynamic analysis of buildings and bridges. The foundation of this method lies in the theory of random vibrations. Specifically, modal combination rules, such as the widely used CQC formula, are derived from consideration of the stationary response of linear structures subjected to wide-band stochastic excitations. These rules are developed under certain assumptions that limit the scope of their applicability. Unfortunately most engineers are not aware of these limitations and use the response spectrum method for situations where it may not work well. The near-field ground motion is one such case.

The fundamental assumptions behind conventional response spectrum methods are as follows: (a) the ground motion has a strong-motion duration of nearly constant intensity, which is several times longer than the fundamental period of the structure, (b) the ground motion has a broad bandwidth, i.e., a broad band of frequencies significantly contributes to the total motion, and (c) the structural response is mainly contributed by modes of the structure that have frequencies within the dominant range of input frequencies.

In the case of near-field motions, assumptions (a) and (b) may be violated. Due to the directivity effect, the near field motion typically has a short strong-motion phase. Furthermore, the motion often has a distinct acceleration or velocity pulse (the "fling") with a narrow frequency content. The structural response to such a pulse is far from being near stationary. Furthermore, due to the narrow band-width, the correlation between modal responses under such a pulse can be very different from that used in the CQC rule. It is proposed to develop a response spectrum method specifically designed for near-field ground motions, properly accounting for the short-duration, pulse-type motion.

The near-field motion offers additional challenges for analysis of multiply-supported structures, such as bridges. In the near-field region the nature of the ground motion can rapidly change with distance due to the directivity and extended source effects. These variations may depend on the orientation of the bridge relative to the source, i.e., whether it is parallel, normal or at an angle with respect to the fault. As a result, the supports of a bridge situated in the near-field region could experience strongly varying motions, even for moderate span lengths. The response spectrum method for near-field motions needs to be extended to account for the differential support motions.

V – Statement of Urgency and Benefits

The validity of existing response spectrum methods for near-field ground motions is in doubt. The error in application of existing methods needs to be examined and improved combination rules need to be developed that properly account for the special characteristics of near-field ground motions.

VI – Related Research

A numerical study of preliminary nature by A. Chopra on the applicability of response spectrum methods to near-field ground motions is available. No rigorous evaluation of the error involved or formulation of a new combination rule has been made. The proposed research will make use of recorded as well as simulated ground motions, including the Caltrans-funded simulations being developed by D. Dreger at UC Berkeley.

VII – Deployment Potential

The near-field ground motion is becoming of increasing concern in design of bridges. An improved modal combination rule for such ground motions will have immediate use.